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CONTROL OF BLACK SPOT OF ROSES WITH SULPHUR-COPPER DUST

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Fig. 1. Rose plants from commercial fields. On left, plant dusted with sulphur-copper mixture; nondusted plant on right. Note the larger plant and more abundant foliage as a result of controlling the black-spot disease.

Premature defoliation of field-grown rose plants by the black-spot disease has been a major problem with commercial rose growers in East Texas. This loss of foliage has resulted in weakened bushes, die-back, low-grade market stock and poor growth or survival of the plants following transplanting.

After several years of research on this disease, an effective sulphur-copper dust treatment has been developed at Substation No. 2, Tyler. In these experiments, the most effective dusts have contained about 90 percent of an unconditioned 325-mesh sulphur and about 10 percent of an insoluble copper compound. Satisfactory control of black spot was obtained when the dust applications were started at the first symptoms of the disease and continued at weekly intervals until July after which bi-weekly dustings were made. From 15 to 25 pounds of dust per acre at each application has been found the most practical dosage.

The use of this dust in the manner described has resulted in successful control of black spot, maintenance of abundant foliage on the plants throughout the growing season, and high quality plants that live and grow well following transplanting, shipment, or storage.

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CONTROL OF BLACK SPOT OF ROSES WITH SULPHUR-COPPER DUST[1]

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Black spot is a fungous disease of the rose plant that attacks the leaves during rainy, humid weather (5). It is caused by the fungus, *Diplocarpon rosae.* As the name of the disease implies, somewhat circular, black-colored spots (fig. 2) are formed usually on the upper leaf surface causing the leaf to become yellowish. Affected leaves usually are shed from the plant (fig. 1). This loss of foliage deprives the plant of much of its needed food materials that are synthesized in the leaves, resulting in the development of weak plants. Consequently, the younger twigs and terminal branches are unable to carry on their normal functions and a condition known as die-back (fig. 3) also occurs (10). Black-spot infections are often found on the stems of rose plants and these cane lesions are believed (9) to be responsible for much of the carry-over of the fungus through the winter.

Rose varieties show marked variations in resistance to black spot. Some hybrid tea roses such as Caledonia, Dame Edith Helen, Julien Potin, and others are very susceptible while varieties such as Radiance, Etoile de Hollande, and Edith Nellie Perkins are somewhat resistant. Most of the popular commercial varieties are sufficiently susceptible to black spot to require fungicidal treatments during the growing season, especially when rains are likely to occur.

The suggested use of spray materials to control black spot of roses probably began about 1888 when Scribner (15) recommended applications of Bordeaux mixture. Among the later more extensive experiments with fungicides to control this disease, were those under the direction of Massey at Cornell University in cooperation with the American Rose Society, conducted during the years 1929-1932. The conclusions of those investigations presented by Parsons and Massey (13) were that dusting was superior to spraying and that a mixture of dusting sulphur and lead arsenate was preferred to other fungicides tried. Early experiments in Texas on the control of black spot included spraying tests, especially with Bordeaux mixture (3), as well as dusting. Later, the spraying work was discontinued owing to the difficulties of hauling heavy sprayers through the light sandy soil, inadequate water supply near the fields, and the necessity of applying a fungicide quickly to extensive areas in critical periods. Good control of black spot was obtained experimentally by Boyd and Taubenhaus (3) as early as 1935 with a dust mixture of 10 parts sulphur, 1 part monohydrated copper sulphate, and 1 part Paris green. In 1936, it was reported (2) that sulphur used in combination with various insoluble copper compounds, or Bordeaux mixture plus wettable sulphur also gave good control of black spot in the field. At the same time, a combination

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[1]Acknowledgment is made of the cooperation of the Freeport Sulphur Company, the Texas Gulf Sulphur Company in this work and the rose growers in whose fields the investigations were conducted.

[2]Formerly at Substation No. 2, Tyler; now at Substation No. 5, Temple, Texas.

of wettable sulphur and Cuprocide inhibited the germination of Diplocarpon spores, when used in suspension on glass slides in the laboratory, to a greater extent than either of the two materials used alone (1). Under conditions in Texas from the 1935 experiments up to the present time, the research data have shown a marked difference in favor of the mixture containing sulphur and a small amount of an insoluble copper fungicide. Emphasis has been placed on such mixtures in these black-spot control experiments.

Although mixtures of sulphur and copper constitute relatively new fungicidal materials, combinations of these substances have been used successfully in controlling plant diseases during the past ten years. As a spray, Bordeaux mixture with wettable sulphur added was found effective

Fig. 2. Black-spot lesions on rose leaflets.

for Dothiorella rot of avocado in California (4), fig rust in Texas (14), and for early blight of celery in Florida (17). Used as dusts, sulphur-copper mixtures were reported to give practical and economical control of Cercospora leaf spot of peanuts in North Carolina (16). In Michigan (12), Cuprocide-sulphur-talc mixtures are reported to have given "superior control" of early and late blights of celery. Preliminary reports of the effectiveness of sulphur-copper fungicides for controlling black spot of roses in Texas were published in 1939 (6), 1941 (7), and in 1942 (8). More recently, those same materials have shown up well in tests on black-spot control in New York (11).

Fig. 3. Die-back of rose stem on right; healthy stem on left. Defoliation of rose plants by black spot results in increased amounts of die-back, although the black-spot fungus is not directly responsible for the dying-back of the stems.

MATERIALS AND METHODS

Many of the experiments at Tyler were conducted in commercial rose fields while certain phases of the work that demanded closest attention were conducted at the Experiment Station. Care and management of the rose bushes in these nurseries were under the direction of the grower and were normal in all respects except for the dust treatments which were applied by the Station workers. Different experiments involving new fields,

Table 1. Composition and source of materials used in dusting experiments with roses.

Trade name	Constituents	Source[1]
Basi-Cop	Basic copper sulphate (52% Cu.)	Sherwin-Williams Co., Cleveland, Ohio
Bancroft clay	Fine clay (for diluent)	United Clay Miners Corp., Trenton, N. J.
Bentonite	300-mesh bentonite (clay)	Wyodak Chem. Co., Cleveland, Ohio
Copper Hydro 40	Copper hydroxide (26% Cu.)	Chipman Chem. Co., Bound Brook, N. J.
Copper oxychloride sulphate	Copper oxychlor. & bas. sulph. (55% Cu.)	Harshaw Chem. Co., Cleveland, Ohio
Copper oxychloride sulphate	Copper oxychlor. & bas. sulph. (23% Cu.)	Rohm & Haas Co., Philadelphia, Pa.
Cuprocide	Cuprous oxide (88% Cu.)	Rohm & Haas Co., Philadelphia, Pa.
Cuprocide GA	Cuprous oxide (86% Cu.)	Rohm & Haas Co., Philadelphia, Pa.
Cupro-K	Copper oxychloride (25% Cu.)	Rohm & Haas Co., Philadelphia, Pa.
Dow copper	Magnesium and copper compound	Dow Chem. Co., Midland, Michigan
Gen. Chem. Sulphur-Copper	325-mesh sulphur:SprayCop (90-10)	General Chem. Co., New York, N. Y.
Grasselli IN-877A6	An organic copper compound	E. I. du Pont Co., Wilmington, Delaware
Loomkill talc	Fine talc (for diluent)	W. H. Loomis Talc Corp., Gouverneur, N. Y.
Potassium permanganate	$KMnO_4$, 200-mesh	Carus Chem. Co., La Salle, Illinois
Pyrax	A pyrophyllite diluent	R. T. Vanderbilt Co., New York, N. Y.
SprayCop	Basic copper sulphate (34% Cu.)	General Chem. Co., New York, N. Y.
Sulphur, Chipman Brand	98% sulphur, 325-mesh	Chipman Chem. Co., Bound Brook, N. J.
Sulphur, Electric Brand	99.8% sulphur, 325-mesh	Stauffer Chem. Co., Houston, Texas
Sulphur, Mike Brand	95% sulphur	Dow Chem. Co., Midland, Michigan
Sulphur, Micronized Brand	95% sulphur, "2000-mesh"	Micronizer Processing Co., Moorestown, N. J.
Sulphur, Owl Brand	99.5% sulphur, 325-mesh	Stauffer Chem. Co., Houston, Texas
Sulphur, Perfection Brand	93% sulphur, 325-mesh	Stauffer Chem. Co., Houston, Texas
Sulphur, Spider Brand	97.5% sulphur, 325-mesh	Southern Acid & Sulphur Co., St. Louis, Mo.
Sulphur, Swan Brand	97.5% sulphur, 325-mesh	Stauffer Chem. Co., Houston, Texas
Tri-Basic Copper Sulphate	Basic copper sulphate (34% Cu.)	Tennessee Copper Co., Copperhill, Tenn.
"34" Copper Fungicide	Basic copper sulphate (53% Cu.)	Tennessee Copper Co., Copperhill, Tenn.
Yellow Cuprocide	Cuprous oxide (83% Cu.)	Rohm & Haas Co., Philadelphia, Pa.
Zinc Coposil	Copper and zinc compounds (19% Cu.)	Calif. Spray-Chem. Corp., Richmond, Calif.

[1]Appreciation is expressed for materials contributed by their manufacturers or distributors.

different varieties and usually somewhat different fungicidal materials were conducted each year. In many cases the Caledonia variety was used because of its high degree of susceptibility to black spot. The location of the experiment, size of plots, and such other variables as types of dusts used (table 1) and number of applications made are given separately in the presentation of work year by year. The number of replications depended on the size of the field and the number of bushes of a selected variety available. The various sulphur-copper mixtures were prepared at first through the cooperation of manufacturers of fungicides; later they were made at the Station with a Messinger dust mixer and hammermill. During 1941 and 1942 one commercially prepared dust was also used. In the early experiments on a small scale, the fungicidal dusts were applied with a two-quart Niagara plunger-type hand duster. Later a Root Model C2 "Challenge" hand-crank, rotary duster was used in large plots. Accurate records of the actual amounts of dust applied were kept by weighing the duster and fungicide before and after each treatment. In some cases the dust applications were made at definite, regular intervals. In other cases the applications were made with reference to local rainfall conditions, since infection was known to occur during wet weather (5). Counts of black-spot infection on individual leaflets were made in the field during the growing season. Final data as to the effectiveness of the treatments consisted of the weights of the bushes at digging time, usually in December.

FIELD EXPERIMENTS WITH SULPHUR-COPPER FUNGICIDES

Comparison of a Spray and Dust Treatment

Previous laboratory and field tests led in 1937 to field trials of a dust mixture containing sulphur, Cuprocide, and lead arsenate, and of a spray material composed of Bordeaux and wettable sulphur. Both of these mixtures were effective in reducing black spot and die-back. However, there was a slight burning of the foliage with both materials.

Sulphur-Copper-Lead Arsenate Dust Compared with Plain Sulphur

In 1938, the sulphur-Cuprocide-lead arsenate mixture was compared with plain 325-mesh dusting sulphur on roses, variety Luxembourg, and was found to give better control of black spot and heavier bushes than plain sulphur. At three locations, the plants dusted with sulphur-Cuprocide-lead arsenate outweighed those dusted with plain sulphur by 31, 21, and 6 percent. There was slight burning of the foliage from both treatments and it was suspected that lead arsenate was unnecessary for roses under these conditions. Although early in November the differences in amount of black spot were only 1, 2, and 3 percent less with the sulphur-Cuprocide-lead arsenate combination than with sulphur dust alone, the differences in black spot had been greater earlier in the season. Consequently, the weight of bushes at the end of the season was considered the best measure of the accumulative effect in controlling the black-spot disease.

Comparison of Sulphur-Copper-Lead Arsenate Dust with Sulphur-Copper Dust

In 1939 the fungicides tested included sulphur-Cuprocide (10:1) as well as sulphur-Cuprocide-lead arsenate (10:1:1). In addition to the Cuprocide mixtures just named, mixtures of sulphur and "34" Copper Fungicide with and without the lead arsenate were also tried. These were compared with six different brands of dusting sulphur. During this season, the sulphur-copper and sulphur-copper-lead arsenate mixtures, in general, gave better control of black spot and larger bushes than dusting sulphur alone. Sulphur-copper mixtures without the lead arsenate were practically as good as those with lead arsenate and the "34" Copper Fungicide appeared to be as suitable and effective as the Cuprocide. The weather in 1939 was unfavorable for black-spot infection and only slight differences were obtained in favor of the dusted plants.

Tests of Different Proportions of Sulphur and Copper

The 1940 season was wetter than usual and an abnormal amount of black spot occurred. Various proportions of sulphur and copper materials were included in the field tests (table 2) at M. Balch's Nursery, fourteen applications of the fungicides were made from May 8 to September 11, using a 2-quart plunger-type hand duster. There were 60 plants in each plot (3 rows wide by 20 plants long) and 4 plots of the same treatment were replicated systematically in each field. Data were taken from 10 consecutive plants located in the center row of each plot. Swan Brand sulphur was used and the treatments were begun only after black spot was seen in the field. Applications of fungicides were made at weekly intervals until July 1 and every two weeks thereafter until near the end of the growing season. (This schedule of applications was followed in subsequent tests unless otherwise specified).

As may be seen in table 2, the sulphur-copper mixtures were again superior to plain sulphur and the effectiveness of the mixtures tended to

Table 2. Effects of dusting roses (var. Luxembourg) with various fungicidal materials in 1940; average of 4 replications.

Fungicide[1]	Leaflets with black spot Oct. 22	Wt. of 10 bushes Dec. 20	Increase in weight over check
	percent	lb.	percent
None (check)	36.4	2.2	0
Sulphur:Cuprocide GA (99:1)	29.9	2.8	27
" " " (96:4)	21.6	3.0	36
" " " (94:6)	24.2	3.1	41
" " " (90:10)	19.0	4.0	82
Sulphur:"34" Copper Fungicide (99:1)	22.9	3.0	36
" " " " (96:4)	27.2	3.0	36
" " " " (90:10)	24.6	3.6	64
" " " " (85:15)	18.1	3.3	50
Sulphur:Grasselli IN (90:10)	27.4	3.7	68
Sulphur:Basi-Cop (90:10)	25.8	3.2	45
Sulphur	32.9	2.8	27
Sulphur:$KMnO_4$[2] (97:3)	24.8	3.0	36
Clay:$KMnO_4$[2]:wheat flour (89:3:8)	28.7	2.1	–5

[1]A conditioned 325-mesh sulphur was used in each sulphur-containing dust.

[2]Potassium permanganate (200-mesh).

increase in proportion to the concentration of copper. The dusts containing the highest proportions of copper, in case of both Cuprocide and "34" Copper Fungicide, showed indications of injury to the leaves during midseason so that the optimum concentration of the copper compound for field use was considered as 6 percent for Cuprocide and 10 percent for "34" Copper Fungicide. The other copper materials tested also appeared favorable in mixtures with sulphur.

Tests with Conditioned and Unconditioned Sulphur, Sticking Agents, and Various Copper Compounds

Many brands of dusting sulphur are conditioned with a small percentage of a material such as clay, magnesium carbonate, or tricalcium phosphate to make the sulphur flow more readily. Wet weather conditions in 1941 again favored black-spot development. In some cases, small plots, 3 rows wide by 30 feet long (table 3), were used to compare a wide variety of copper fungicides mixed with sulphur, in both conditioned and unconditioned forms. These dusts were applied with the 2-quart plunger-type dusters. Black-spot leaf counts were made in October and weights of bushes were recorded at digging time in December. The results showed that several different materials could be used safely with sulphur as dust fungicides for roses. Little or no injury was apparent from any of the

Table 3. Control of rose black spot with fungicidal dusts[1] as shown by leaflet infection and weight of bushes at harvest—Luxembourg variety—1941.

Fungicide	Condition of dust	Leaflets with black spot Sept. 17	Wt. per 10 bushes Dec. 9
		percent	lb.
Balch's Nursery			
None (check)	—	23	3.5
Sulphur:"34" Copper Fungicide:bentonite (80:10:10)	Satisfactory	14	4.0
Sulphur:Tri-Basic Copper Sulphate (93.6:6.4)	"	16	4.0
Sulphur:"34" Copper Fungicide:flour (80:10:10)	"	18	3.8
Sulphur:Cuprocide (94:6)	Became lumpy	8	3.7
Sulphur:Grasselli IN (90:10)	Satisfactory	17	3.6
Sulphur:Basi-Cop (90:10)	Clogged duster	12	3.6
Sulphur:"34" Copper Fungicide (90:10)	Satisfactory	11	3.5
Sulphur:Copper oxychloride sulphate (90:10)	"	13	3.5
Sulphur:SprayCop (90:10)	"	15	3.5
[2]Sulphur:"34" Copper Fungicide (90:10)	"	13	3.4
Sulphur:Cuprocide:bentonite (84:6:10)	Became lumpy	9	3.3
[2]Sulphur:Cuprocide (94:6)	Satisfactory	15	3.0
Sulphur:Cupro-K (90:10)	"	11	2.8
Pyrax:Cuprocide (94:6)	Drifted	16	2.8
Ginn's Nursery			
None (check)	—	28	2.8
Sulphur:Zinc Coposil:bentonite (80:10:10)	Satisfactory	21	3.2
Sulphur:Dow Copper (90:10)	"	18	2.9
[3]Sulphur:Copper Hydro 40:bentonite (80:10:10)	"	19	2.9
Pyrax:Copper Hydro 40:bentonite (80:10:10)	Light, drifted	24	2.9
[2]Sulphur	Satisfactory	26	2.7
[2]Sulphur:bentonite (90:10)	"	20	2.5

[1]Eleven applications were made from May 22 to Aug. 28. There were between 60 to 100 bushes per plot (3 rows wide and 30 feet long), and 6 plots of the same treatment were replicated in each field. Data were taken from 5 consecutive plants in the middle row of each plot for black-spot counts and from 10 plants for weights.

[2]Swan Brand (conditioned) sulphur; all other mixtures made with Owl Brand (unconditioned).

[3]Chipman Brand sulphur.

fungicides during this season. In most cases an unconditioned 325-mesh sulphur (Owl Brand) was found as suitable for the sulphur-copper mixtures as the conditioned 325-mesh sulphur (Swan Brand). The benefit of bentonite and flour as sticking agents was questionable. Failure to get good control of black spot was due to the infrequency of dust application during the latter part of the season (bi-weekly treatment) when an unusually heavy amount of rainfall occurred.

Better results were obtained (table 4) from larger sized plots, 7 rows wide and 27⅔ or 55⅓ feet long and where a rotary duster was used instead of the small plunger-type duster. These tests were devised mainly to

Fig. 4. Control of black spot on the Caledonia variety in the field by dusting with sulphur-copper fungicides. A, Bushes dusted after each rain; B, Dusted once a week; C, No dust applied; D, Field showing dusted areas at each end and a nondusted plot in the center.

determine whether or not unconditioned sulphur would react as well as conditioned sulphur in the sulphur-basic copper sulphate mixture. Conditioners serve to prevent lumping and to facilitate application with mechanical dusters, however, with copper materials added to the sulphur, it was thought the usual conditioner might be unnecessary. Another purpose was to test bentonite as a sticking agent in the sulphur-copper dust. The basic-copper-sulphate ("34" Copper Fungicide) was selected in preference to cuprous oxide (Cuprocide) because of its lower cost and because only questionable differences had occurred in the results comparing the two materials. Dusts were applied with rotary hand dusters in these tests. As usual, fungicidal treatments were withheld until black spot appeared, continued regularly each week until July 1, and thereafter only once in two

weeks until near the end of the growing season. The weights of fungicidal materials used were calculated from those actually applied. An effort was made to apply the same amount of each of the different materials, however, with differences in flowability through the dust gun, this was difficult to accomplish.

The data on the weights of bushes at harvest time show quite conclusively the benefits from use of the sulphur-copper dust. There seemed to be no advantage in using a previously-conditioned sulphur in the mixture. Also the addition of bentonite to the fungicide as a sticking agent was not beneficial. The superiority of the sulphur-copper dust in comparison with plain dusting sulphur was again demonstrated in 1941.

Comparisons of Different Grades of 325-Mesh Sulphur and Various Copper Compounds

The 1942 season also was favorable for the occurrence and spread of the black-spot disease. Benefits from use of fungicides similar to those in previous seasons were again obtained in most of the experiments. This year all dust materials were applied with rotary hand dusters. A comparison was made of the effects of two grades of 325-mesh sulphur in mixture with basic copper sulphate. One sulphur was ground to such fineness that at least 93 percent of the particles would pass through a sieve having 325

Table 4. Comparison of sulphur and sulphur-copper mixtures for the control of black spot on several varieties of roses as shown by weight of bushes at harvest, 1941. Av. wt., pounds per 10 bushes.

Location and variety		Check	Sulphur (conditioned)	Unconditioned sulphur:"34" Copper Fungicide:bentonite (80:10:10)	Conditioned sulphur:"34" Copper Fungicide (90:10)	Unconditioned sulphur:"34" Copper Fungicide (90:10)
Zorn Nursery[1]						
Talisman[2]		4.0	5.1	6.2	5.6	6.9
Etoile de Hollande		3.7	4.6	4.5	4.4	5.0
Columbia		4.1	4.0	4.4	5.1	5.5
E. G. Hill		4.1	4.8	4.5	5.3	5.2
Mme. Edouard Herriot		3.5	3.9	4.4	4.5	5.0
President Hoover[2]		4.7	5.8	6.5	6.0	7.0
Av. increase over check—percent		—	17	27	28	44
Whiteside Nursery[1]						
Hinrich Gaede		2.1		3.4		3.0
Mrs. Pierre S. du Pont		1.5		2.1		1.9
Caledonia[2]		1.6		2.7		2.1
Talisman		3.5		4.6		5.3
Etoile de Hollande		3.2		4.3		5.6
Av. increase over check—percent		—		44		50
Pounds of dust per acre per application	Zorn's	0	19.9	19.4	15.9	16.9
	Whiteside's	0		26.4		22.7

[1]In the Zorn Nursery the plots were 7 rows wide (1 row per variety except as noted) and 55⅓ ft. long (0.04 acres, approximately 400 bushes per plot) and 3 plots of the same treatment (12 applications) per replication. In the Whiteside Nursery the plots were 7 rows wide (1 row per variety except as noted) and 27⅔ ft. long (0.02 acres, approximately 200 bushes per plot) and 4 plots of the same treatment (14 applications) per replication. Data were taken from only 5 of the 7 rows, leaving two outside guard rows.

[2]Average from 2 rows of this variety.

meshes to the linear inch. The other was of such fineness that at least 98 percent of the particles would pass through a similar sieve. Both were unconditioned grades of sulphur (Owl Brand) and the latter (98 percent) was the same type as used in the 1941 experiments. As in previous years, dusting was withheld until black spot was observed and the applications were made at weekly intervals until July 1; thereafter applications were made every two weeks until the end of September.

Other comparisons again were made of different copper materials in mixtures with the sulphur. In these tests, plots were two hundredths of an acre in size (7 rows wide by 27⅔ feet long) with 150 to 200 bushes per plot. Data were taken from centrally located bushes in each plot. The results (table 5) showed only slight and probably insignificant differences between the two grades of sulphur in mixture with "34" Copper Fungicide. The cheaper grade (93 percent 325-mesh) was almost as good as the more expensive grade (98 percent 325-mesh). Among the different copper compounds, Copper Hydro 40, Dow copper, and Cupro-K provided the best black-spot control in that order and all of these were equal to or better than "34" Copper Fungicide. The cost of these materials would be the most important factor in choosing a copper fungicide for field utilization in a mixture with sulphur.

Table 5. Results of various fungicidal dust treatments in 1942 for the control of rose black spot.

Fungicide	Lbs. per acre per application	Leaflets with black spot	Wt. of 10 bushes	Increase in wt. over check
		percent	lb.	percent
Atkins' Nursery[1]				
None (check)	0.0	48	2.3	—
Sulphur (98% 325-mesh): Dow Copper (90:10)	23.7	27	3.2	39
Sulphur (98% 325-mesh): "34" Copper Fungicide (90:10)	26.1	21	3.1	35
Sulphur (93% 325-mesh): "34" Copper Fungicide (90:10)	29.3	30	3.0	30
Sulphur[4]:Yellow Cuprocide (96:4)	26.7	23	2.8	22
Talc:"34" Copper Fungicide (90:10)	21.9	35	2.5	9
Green's Nursery[2]				
None (check)	0.0	19	4.8	—
Sulphur (98% 325-mesh):Copper Hydro 40 (90:10)	27.1	15	7.0	46
Sulphur (98% 325-mesh):Cupro-K (90:10)	21.2	18	5.7	19
Sulphur (98% 325-mesh):"34" Copper Fungicide (90:10)	24.0	10	5.6	17
Wiley's Nursery[3]				
None (check)	0.0	36	2.3	—
Sulphur (98% 325-mesh):"34" Copper Fungicide (90:10)	30.0	23	2.8	22
Sulphur[4]	33.8	24	2.7	17
Sulphur:Copper (90:10)—General Chem. Co.	33.1	21	2.4	4
Sulphur (98% 325-mesh):Zinc Coposil (90:10)	31.4	44	2.4	4

[1]Francis Scott Key variety, 15 applications (May 6-Sept. 23). Leaf counts were made Sept. 24. Bushes were weighed Dec. 1, 1942. Averages of five replications are given.

[2]Talisman variety, 9 applications (June 7-Sept. 23). Leaf counts were made Sept. 25. Bushes were weighed Dec. 8, 1942. Averages of four replications are given.

[3]Kaiserin Auguste Viktoria variety, 12 applications (May 27-Sept. 23). Leaf counts were made Oct. 1, 1942. Bushes were weighed Jan. 12, 1943. Averages of four replications are given. The sandy field, excessive pruning back of the young plants, and the variety used account for the small size of the bushes in this test.

[4]Swan Brand sulphur; all other sulphur mentioned in this table was Owl Brand, with the exception of General Chemical Company's sulphur-copper dust.

Another experiment in 1942 tested the effect of adding cotton seed oil (2 percent of the dust by weight) as a sticking agent in the sulphur-copper dust. An estimate of the amount of black spot on September 23 was less than 0.1 percent of the leaflets affected. However, on the basis of weight and grade of bushes, those dusted with the plain sulphur-copper mixture were somewhat better than those which received the mixture plus the oil. Although no injury from the oil was apparent on the bushes, the oil interfered with the dusting process and made application of the dust more difficult.

Fig. 5. Different methods of applying sulphur-copper dust in the field. Above, a rotary crank duster used in much of the experimental work. Below, a tractor-operated power duster commonly used in commercial rose fields.

METHODS OF APPLYING DUST FUNGICIDES

Dusting of Plants from Above as Compared with Dusting from Below

An experiment was conducted with field-grown roses in 1938 in which weekly applications of two fungicides were made with a Niagara plunger-type 2-quart hand duster. In certain plots the nozzle of the duster was adjusted to project the dust upward underneath the foliage. In other cases the dust was forced down onto the upper surfaces of the leaves. The two fungicides used were plain 325-mesh dusting sulphur (Swan Brand) and a mixture of sulphur, Cuprocide, and lead arsenate (10:1:1). Single row plots with 15 plants per plot were utilized with untreated rows on each side of the test row and with 10 untreated plants between plots within the row. Treatments were begun April 20 and continued until October 26, making a total of 28 applications. An average of 14 pounds of fungicide per acre was applied at each dusting. Data were taken from 10 plants centrally located in each plot (table 6). The results show that directing the dust downward was usually more effective than trying to direct it upward onto the foliage.

Effects of Varying the Rate of Dust Application

In 1941 an experiment was conducted in W. B. McGinney's field to compare the effects of applying different quantities of fungicide on field-grown roses. The plots were 7 rows wide by 27⅔ feet long (0.02 acres or 150 to 200 bushes each). The dust mixture used contained 90 parts Owl Brand sulphur and 10 parts "34" Copper Fungicide (90:10). This was ap-

Table 6. Control of rose black spot by dusting plants from above compared with forcing the dust upwards from below, 1938.

Treatment	Direction of dusting	Leaflets with black spot Nov. 1-10	Wt. of 10 bushes
		percent	lb.
		Pittman Field—var. Luxembourg (4 replications)	
None (check)	—	12	3.3
Sulphur	Upward	6	3.9
"	Downward	6	4.0
None (check)	—	16	2.8
S-C-LA[1]	Upward	4	4.2
"	Downward	3	4.4
		Shamburger Field—var. Luxembourg (3 replications)	
None (check)	—	25	4.5
Sulphur	Upward	5	4.6
"	Downward	5	5.6
None (check)	—	23	4.4
S-C-LA[1]	Upward	5	5.5
"	Downward	6	4.8
		McGinney Field—var. Dame Edith Helen (4 replications)	
None (check)	—	24	3.3
Sulphur	Upward	9	3.0
"	Downward	8	2.9
None (check)	—	17	3.2
S-C-LA[1]	Upward	7	3.8
"	Downward	8	5.5

[1]Sulphur:Cuprocide:lead arsenate (10:1:1).

plied to the Mrs. Erskine Pembroke Thom variety at three rates of application averaging 13, 28, and 46 pounds per acre for each application. As in most other tests, treatments were withheld until black spot was observed. They were made at weekly intervals until July 1, and once every two weeks thereafter until October 1. A total of 9 applications were made between June 19 and October 1.

The results (table 7) show that larger bushes were obtained with the heavier applications of fungicides. Although foliage injury was anticipated from the heaviest applications, the season was such that no burnnig was

Table 7. Effect of different amounts of sulphur-copper dust per application on the control of rose black spot, as shown by amount of foliage and weight of bushes, 1941. Av. of 5 replications.

Amount of dust per application lb.	Number of leaflets per 5 plants Oct. 7	Wt. of 10 plants, Dec. 18 lb.	Incr. in wt. over check percent
None (check)	279	2.1	—
13	416	2.5	19
28	427	2.9	38
46	515	3.2	52

apparent. A graph of the results (fig. 6) shows that the heaviest application tested was possibly insufficient to cause the maximum increase in weight which could be derived, since each increase in amount of dust used

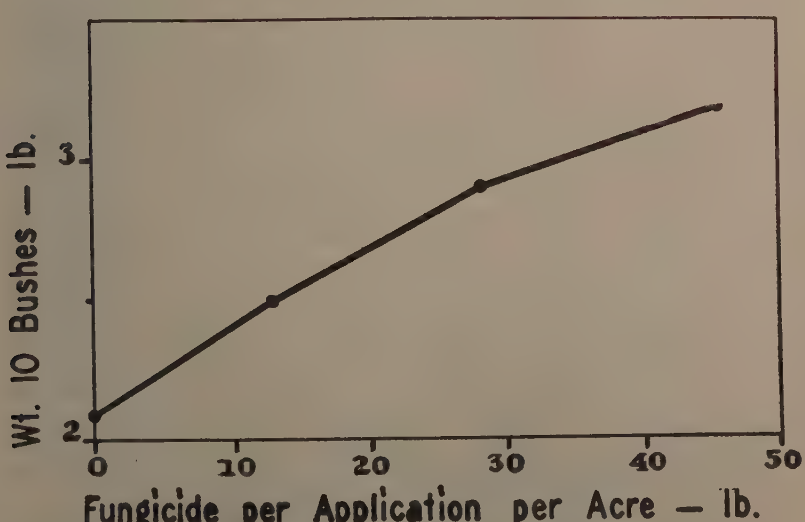

Fig. 6. Graph showing relation of weight of rose bushes to amount of sulphur-copper dust used per acre per application.

resulted in proportional increases in the weight of bushes. Although there was considerable variation in the number of leaves per plant on October 7, the percentage of leaves infected with black spot on that date did not differ significantly between the different treatments and the records of black-spot infection are omitted from the table.

This experiment demonstrated the beneficial effect that the extremely heavy applications of the fungicide used might have on a variety known to be very liable to defoliation by black spot. In spite of the lack of injury from the heaviest treatment, however, such heavy amounts would not be recommended for practical purposes.

Time, Frequency, and Amount of Dust Application

Since it was known that black spot spread only during rainy periods, it was important to find out the effectiveness of a fungicide applied following rains as compared with pre-rain applications and how long after a rain application could be made and still prevent black-spot infection.

Greenhouse test. Potted bushes of the Caledonia variety were used in a greenhouse experiment to determine the best time to apply the fungicide. Young plants with new, tender foliage were treated as shown in table 8. Inoculation was accomplished by atomizing the upper surface of the leaves with a suspension of conidia obtained from leaf lesions. Artificial rainfall produced by means of a fine mist from a hose sprinkler, directed so that the drops of water fell on the leaves from above, was used in certain cases as noted. The period of sprinkling was two minutes.

Table 8. Results of greenhouse tests with potted plants to ascertain the most effective time, in relation to occurrence of rain, for applying fungicides for black-spot control.

Treatment	Av. number of black-spot lesions per 100 leaflets
Plants treated and inoculated April 25; data on May 5, 1942.	
Check[1]	0
Artificial rain; inoculated; no dust	692
Dusted; artificial rain; then inoculated	222
Inoculated; dried for 1 hr.; then dusted	3
Dusted; then inoculated	2
Plants inoculated June 23; data on July 7, 1942.	
Check[1]	0
Inoculated; no dust	220
Inoculated; dusted immediately	0
Inoculated; dusted 4 hrs. later	0
Inoculated; dusted 8 hrs. later	4
Inoculated; dusted 12 hrs. later	1
Inoculated; dusted 24 hrs. later	0
Inoculated; dusted 36 hrs. later	40
Inoculated; dusted 48 hrs. later	83
Inoculated; dusted 72 hrs. later	124
Inoculated; dusted 96 hrs. later	144
Plants inoculated July 8; data on July 21, 1942.	
Check[1]	0
Inoculated; no dust	188
Dusted; artificial rain; then inoculated	106
Inoculated; dusted immediately	0
Inoculated; dusted 24 hrs. later	25
Inoculated; dusted 36 hrs. later	51
Inoculated; dusted 48 hrs. later	59
Inoculated; dusted 72 hrs. later	270

[1]Artificial rain for 2 minutes but no inoculation or fungicide.

Fungicide applications were made with a two-quart plunger-type hand duster, using a light but thorough coverage with sulphur-copper dust (Owl sulphur: "34" Copper Fungicide, 90:10). The plants were maintained over a pan of water in a shaded glass humidity chamber for 72 hours following the treatment indicated.

Data on infection were obtained by counting the number of leaf spots which developed. It was found that the protective value of the fungicide was greatly lost if the foliage was sprinkled with water for only two minutes following dusting. The fungicide was most effective when applied immediately after inoculation, but partial control of black spot was obtained even when application was delayed as long as two days after inoculation. This experiment indicates that the best time to apply a dust fungicide under outdoor conditions would be as soon as possible after each rain.

Field test. An experiment was conducted with Caledonia roses in the field to compare regular weekly dusting with dusting within 24 hours after each rain which was considered sufficient to spread the spores causing black spot. The amount of rain was not measured but was estimated to be 0.1 inch or more. The dimensions of the field were such that in replications 1 and 2 the plots were each 6 rows wide and 27 feet long; in replications 3 and 4 the plots were 5 rows wide and 31 feet long, making about 0.016 acre or approximately 200 bushes per plot. The dust used consisted of 90 parts Owl sulphur (98% 325-mesh) and 10 parts "34" Copper Fungicide. Treatments were made from May 4 to September 28 with 22 applications for the weekly and 28 for the after-rain treatments. An average of 27 pounds of dust was used per acre at each application. This season, no injury from the fungicide was apparent even with the large number of applications.

The data in table 9, taken from centrally located bushes in each plot (fig. 4) show only a slight difference between the dustings within 24 hours after each rain and those made regularly once each week. However, for this particular season, with an abnormally high rainfall, the system of applying a fungicide within 24 hours after each rain required more applications than the once-a-week treatment. Also, the total number of dustings required was greater than normal due to the early black-spot appearance in the field. (Methods to delay the development of black spot in fields are discussed under the next heading).

With regard to the frequency of application and the amount of sulphur-copper dust required, it would appear from experiments and observations to date that fungicides should be withheld until black spot is seen in the field. The treatments should then be made at regular weekly intervals until about July 1. Thereafter the applications should depend on the season. If the weather is generally dry, the dust should be used only after rains and then as soon as possible after each rain that is heavy enough to wash the dust from the foliage. If the weather is generally rainy, then the frequency for economical field treatment should not be oftener than once a week. A normal average for the season would be between 10 and 15 applications. The amount of dust to use depends on the method of applying. If a rotary hand duster (fig. 5) is used, the amount

Table 9. Comparison of weekly dusting and dust application after each rain as to effectiveness in black-spot control—Caledonia variety—1942. Average of 4 replications.

Frequency of application	No. of applications	No. of leaflets per 10 bushes	Leaflets with black spot[2] percent	Percentage of bushes in each of 3 grades[1]			Weight of 10 bushes of various grades[1]—lb.[3]		
				No. 1	No. 1½	Others	No. 1	No. 1½	Others
No dust applied	0	647	32.8	14	38	48	3.5	2.6	1.6
Weekly	22	954	4.4	39	50	11	4.6	3.3	1.8
Within 24 hrs. after rain	28	1271	2.8	35	51	14	4.8	3.5	2.2

[1]Commercial grades of rose bushes: No. 1—three or more strong canes 18 inches or longer; No. 1½—two or more strong canes 14 inches or longer (both grades with good, well balanced root systems); others—inferior to these grades, including culls. This system of grading was adapted from the American Association of Nurserymen Standards.

[2]Black-spot data were taken July 23.

[3]Records of weights and grades were taken December 15.

should be between 20 and 25 pounds at each application. With a power or tractor duster (fig. 5), from 15 to 20 pounds are advised. The amount would be less when the bushes are small and greatest when they reach mature size.

Factors Affecting the Primary Infections of Black Spot in the Field and the Need for Beginning Dust Treatments

Kind of understock. In one field experiment, black spot was observed very early in the season and because of this more dust applications than normal were required. The main reason for the early appearance of the disease in this case was due to the fact that in the same field another experiment was being conducted on the effect of different varieties of understock on the Caledonia scion and the reaction of both understock and scion to black spot. The varieties of understocks used were: Welch multiflora (a recumbent type in general field use), Tate multiflora (an upright form used commercially to a small extent), Texas Wax (a semi-recumbent type in general use several years ago but almost completely replaced now), and *Rosa manetti* (an upright form commonly used for greenhouse propagation but little used for outdoor roses). Of these four varieties the multiflora types were observed to be highly resistant (possibly immune) to black spot. The Texas Wax was quite susceptible and the *R. manetti* was extremely susceptible. *R. manetti* was observed with black spot from the time the first leaves developed on the cuttings until the understock tops were cut off to force out the scion buds. With a great production of spores of the black-spot fungus coming from the understock, there was little chance of the scions escaping infection during their early development.

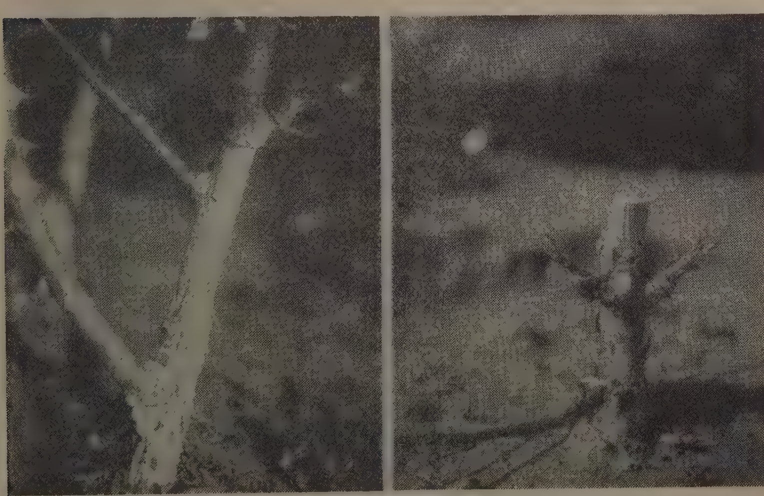

Fig. 7. Close cutting of understock tops and scion to prevent carry-over of black-spot infection. Left: Before pruning, showing scion (the thorny branch) prematurely forced. Right: Good development of lateral buds when scion was cut back close to understock.

The occurrence of the disease was much earlier and more extensive on these plants than on scions of the same variety in other fields where the propagation was done on understocks which were resistant or immune to black spot.

Time of cutting of understocks. Another factor affecting the early incidence of black spot on the scions was the date on which the understocks were cut off causing the scion buds to develop. Any delay in forcing of the scions delays the initial infections of the scions. The extent to which this could be accomplished would depend upon how late in the season the forcing could be done without interfering with the ultimate size and grade of bush at the end of the growing season. The time of cutting-off the understock tops under average field conditions has been from February 1 to April 1, under East Texas conditions. During the early months of the growing season the greatest number of rainy days occur, and these frequent periods of rainfall are conducive to the spread of black spot. Delay in cutting off the understocks and forcing early growth of the scions therefore helps to delay the disease and the need for commencing fungicidal dust treatments.

The question arises as to how late in the growing season the cutting-off can be postponed. Also there is the problem of what should be done with the scions which have forced out before the understock tops are removed (fig. 7). Field observations help to answer both questions. It was noted in 1940 that one of the nurserymen did not do the cutting-off of the understock tops in part of his field until April 22. Bushes which developed from these plants were observed to be equal to or better than others grown that season. Considering the other question as to pruning of the scions which were already forced at the time of the cutting-off operation, they normally were also cut back leaving a stub about two inches in length extending from the bud union. Some scions were observed in fields which were cut back much closer. Due to the fact that cane lesions of black spot can also spread the disease as well as leaf spots, there should be a distinct benefit from cutting back the forced scions as closely as possible.

In 1942 a test was made involving the points just mentioned. It was a nonreplicated trial with half of each row in part of the field forced out 17 days later than the other part. Six varieties of roses were included in the test. One date of cutting off the understock tops was March 24-25; the other was delayed until April 11. At the time of cutting-off, all of the scions which had prematurely forced were cut back to within less than half an inch from the bud union. The results were that black-spot was seen first on May 11 on a few of the plants which were forced earliest while none was observed yet on those cut off last. No injurious effect was noted in those cut off last nor was there any injury apparent from cutting back the prematurely developed scions to less than half an inch in length. Lateral buds developed from the short scion stalk (fig. 7) and in most cases two or more branches grew from the bud unions to form well shaped bushes. The data in table 10 show no disadvantage from the later cutting-off, either in the grade or weight of bushes. The slight difference which did occur was in favor of the later cutting-off. Black spot was controlled with dusting (less than 0.1% of leaflet infection on September 23) and the

Table 10. Effect of time of cutting off understock tops on grade and weight of bushes—1942.

Variety	Grade[1]	Cut off early (March 24-25)		Cut off late (April 11)	
		Number of bushes in each grade	Wt. of 10 plants in each grade lb.	Number of bushes in each grade	Wt. of 10 plants in each grade lb.
Rouge Mallerin	1	142	5.8	108	6.1
	1½	147	4.2	205	4.6
	others	27	2.4	16	1.9
	Total[3]	316	4.8	329	5.0
Etoile de Hollande	1	50	7.4	50	7.7
	1½	91	5.3	82	5.8
	others	15	3.6	9	3.9
	Total	156	5.8	141	6.4
Briarcliff	1	117	8.5	163	8.3
	1½	221	5.9	202	5.8
	others	44	4.0	56	3.8
	Total	382	6.5	421	6.5
Cynthia	1	125	8.0	165	8.4
	1½	245	5.8	190	5.8
	others	86	3.6	61	3.1
	Total	456	6.0	416	6.4
Francis Scott Key	1	40	6.2	45	5.7
	1½	80	4.5	90	4.0
	others	40	2.7	11	2.5
	Total	160	4.5	146	4.4
Dainty Bess	1	65	7.1	40	8.9
	1½	80	5.9	80	6.2
	others	30	4.7	23	4.8
	Total	175	6.1	143	6.7
Total of all varieties	1	539 (33%)[2]	7.17	571 (36%)[2]	7.52
	1½	864 (52%)	5.27	849 (53%)	5.37
	others	242 (15%)	3.50	176 (11%)	3.33
	Total	1645	5.63	1596	5.91

[1]See footnote, Table 9.
[2]Figures in parentheses represent percentage of total number of bushes.
[3]Weighted mean in case of weights of plants.

same amount and frequency of dusting was used for both parts of the field. The difference which occurred, therefore, was attributed to the fact that the earlier cutting-off produced plants which had to be topped back slightly, twice during May, to prevent wind damage and it is believed that the topping back process had a slight stunting effect which was greatest where it was done twice. Our observations indicate that cutting off the understock tops may be withheld until early in April. In order to state how much later it might be postponed without harmful effects, further experimentation would be necessary.

COMPUTED PROFIT FROM DUSTING

It should be noted in a preceding experiment (table 9) that the fungicides not only controlled black spot, reduced defoliation, and produced heavier bushes, but also increased the number of high grade bushes (grades No. 1 and No. 1½). As compared with the nondusted plants the weight of the dusted bushes was 64 percent greater when dust was applied within 24 hours after rains and 57 percent greater when the applications were made once each week. The number of bushes grading No. 1 and No. 1½ was increased by the fungicide treatment from 52 percent for the nondusted plants to 86 percent in the case of the dusting within 24 hours after rains, and to 89 percent by dusting regularly once each week. On a

10,000 bushes per acre basis, the data would represent an average gross increase of about \$284.00 per acre from the use of the dust fungicide, considering only grades No. 1 and No. 1½ at 8 cents per bush and discarding the inferior grades. The cost of dusting within 24 hours after each rain was estimated at \$49.00 per acre for the season (the fungicide at \$5.00 per 100 pounds and 40 cents per acre for labor and machine for each application). On this basis the net increase from dusting was \$235.00 per acre. Actually, under commercial field conditions, the expense of fungicide application would be considerably less because the applications would be commenced later in the season, greater efficiency would be obtained from a power duster, and there would be no nondusted check plots from which the spores would spread infection to the dusted plants.

Varietal differences in susceptibility to black spot and hardiness are quite important from the standpoint of commercial methods and care in the growing of roses. Whereas climbers, hybrid perpetuals, many species roses and varieties of hybrid tea roses, such as the Radiance group, ordinarily grow well and attain good size and grade without any fungicidal treatment, most of the hybrid tea roses, which constitute the main crop, require fungicidal treatment to insure good bushes as grown under conditions in East Texas. In this area, the rainfall is such that black spot is a factor in production at all times during the growing season. A 32-year record of weather at the Tyler substation shows an average of at least 0.1 inch of rain on more than five days a month including the summer period. During the spring months the average is more than eight days per month. Therefore, once the black-spot disease gets started in a field, fungicidal protection should be given throughout the remainder of the growing season.

It would appear advantageous to group the resistant types of roses together in one block and to have the others separate in order to conserve fungicide materials and facilitate the heavier treatment of types and varieties which need protection the most. Many growers already are following this system.

The benefit from the sulphur-copper fungicide has been reported to extend into the storage of the bushes and also their subsequent planting. In one case where the bushes were stored in a mid-western state preparatory to distribution in the spring, there was little or no die-back in the storage of field-dusted bushes, whereas die-back developed in the nondusted plants to varying degrees and even resulted in the complete loss of some bushes. In this case, mention was also made that storage molds were absent from those plants which had been field-dusted, while it occurred on undusted ones in different amounts. If the bushes are in good condition when received for storage, it might not be necessary to spend large sums of money to keep them healthy during the storage period.

EFFECTS OF DUST ON THE SOIL

Where the sulphur-containing fungicide is used year after year on the same area, acidification of the soil may eventually occur to the extent that liming would be required. The soil should be tested for acidity from year to year and limed if the acidity is greater than pH 5-6, which can easily

be ascertained by a simple test. However, too high acidity of the soil would not be expected very soon in the normal production of roses because other crops not receiving the fungicide treatments would be used in rotation and the land would not be in roses more than once in three or four years. Rotation with crops other than roses would largely prevent an accumulation of fungicidal chemicals in the soil.

RECOMMENDATIONS

Rose bushes should be dusted at the first appearance of black spot on the foliage.

Dust the plants with a sulphur-copper mixture containing about 90 percent of unconditioned 325-mesh dusting sulphur and about 10 percent of an insoluble copper fungicide such as basic copper sulphate, "34" Copper Fungicide, Copper Hydro 40, Grasselli IN877A6, SprayCop, Copper Oxychloride-Sulphate, or Cupro-K. Certain sulphur-copper mixtures are now obtainable on the market ready for use. If cuprous oxide (Cuprocide) is used in the mixture, the sulphur should be conditioned.

Repeat applications of the dust at weekly intervals until July (or until hot, dry weather begins), thereafter dust within 24 hours after each rain, but not more often than once a week, until growth of the plants is checked by cool weather.

Use a sufficient amount of dust to cover the foliage lightly. This usually amounts to 15 to 25 pounds per acre at each application depending on the size of bushes and type of dusting machine used.

SUMMARY

An effective sulphur-copper dust fungicide for controlling the black-spot disease of roses has been developed in field tests at Substation No. 2, Tyler. This mixture gave better control of black spot than the pure dusting sulphur, formerly recommended.

Various grades of 325-mesh dusting sulphur have been found satisfactory for mixing with certain insoluble copper compounds in forming the fungicidal dust mixture. Several copper compounds mostly sold under trade names were used in the sulphur mixture with good results in these experiments. Among the most effective mixtures were those containing about 90 percent 325-mesh dusting sulphur and 10 percent of a copper fungicide such as "34" Copper Fungicide, Copper Hydro 40, Cuprocide, Dow copper, Grasselli copper, SprayCop, Copper Oxychloride Sulphate, and Cupro-K.

The addition of wheat flour, cotton seed oil, or bentonite to the sulphur-copper mixture as sticking agents did not improve materially the degree of black-spot control obtained. Unconditioned sulphur was found as satisfactory as conditioned sulphur when used with certain of the copper compounds. Also, a 93 percent 325-mesh grade of sulphur was practically as good as a 98 percent 325-mesh brand for the dust fungicide.

Greenhouse tests with potted roses showed that the sulphur-copper dust was removed from the foliage by a brief period of sprinkling and that the fungicide was most effective in controlling black spot when ap-

plied immediately after inoculation. In corroborative field experiments the best results were also obtained when the fungicide was applied within 24 hours after each rain. This system required an extreme number of applications in certain seasons. The most economical and effective frequency of application appeared to be once regularly each week, following the appearance of black spot, until July 1 and then within 24 hours after rains but not oftener than once a week for the remainder of the season.

With a susceptible variety, Caledonia, the sulphur-copper applications not only reduced black spot and increased the weight of bushes at harvesting time, but also greatly increased the percentage of high grade bushes. Those grading No. 1 and No. 1½ were increased from 52 percent for non-dusted bushes to more than 85 percent for those that had been dusted. The net increase in value from the fungicide treatments was figured at $235.00 per acre in that experiment with the inferior grades not included.

A consideration was made of factors involved in the incidence of black spot in fields. Use of understock varieties which were resistant or immune to black spot delayed infection on the scions. Late cutting-off of the understock tops and pruning back to less than half an inch all prematurely-formed scions resulted in later development of scions and a subsequent delay in the incidence of black spot. Any delay in the occurrence of black spot in a field lessened the amount of fungicidal treatment required.

Directing the dust downward onto the foliage gave as good or better results than projecting it upward from below the leaves. About 20 to 25 pounds per acre of sulphur-copper dust at each application with a rotary hand duster, or 15 to 20 pounds per acre with a tractor power duster were found to give the most satisfactory black-spot control.

Benefits from using the sulphur-copper dust on field roses were also obtained in storage.

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